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System and Method for Performing Flame and Flow Field Diagnostics in a Combustor of a Gas Turbine Engine

Abstract

A combustor including: a combustor case defining a plurality of case apertures; a liner within the combustor case defining a combustion zone and liner apertures through which an airflow flows into the combustion zone; a fuel injector having a fuel channel extending through a first case aperture and the liner, and the fuel channel has a nozzle at the combustion zone through which fuel is injected; an igniter for igniting the combustible mixture of fuel and airflow and providing a flame at the nozzle; and a flame sensor including: a radio frequency transponder, comprising a transmitter-receiver pair, located exterior to the combustor case; a horn antenna disposed in the fuel nozzle, and a tubular waveguide extending from the radio frequency transponder to the horn via one of the plurality of case apertures, wherein the flame sensor is configured to perform flame and flow field diagnostics.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application claims the benefit of U.S. Application No. 63/588,379 filed Oct. 6, 2023, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Exemplary embodiments of the present disclosure pertain to the art of combustors of gas turbine engines and more specifically to a system and method for performing flame and flow field diagnostics in a combustor of a gas turbine engine.

[0003] A gas turbine engine requires the combustor to reliably produce a flame. Testing a flame production in a newly designed combustor and monitoring the flame production in an in-use combustor can help identify and correct issues that could otherwise lead to an inefficient operation of the engine.

BRIEF DESCRIPTION

[0004] Disclosed is a combustor of a gas turbine engine, including: a combustor case defining a plurality of case apertures; a liner within the combustor case defining a combustion zone and liner apertures through which an airflow flows into the combustion zone; a fuel injector having a fuel channel extending through a first case aperture and the liner, and the fuel channel has a nozzle at the combustion zone through which fuel is injected, to produce a combustible mixture with the airflow; an igniter extending through a second case aperture and the liner for igniting the combustible mixture and providing a flame at the nozzle; and a flame sensor including: a radio frequency transponder, comprising a transmitter-receiver pair, located exterior to the combustor case; a horn antenna disposed in the fuel nozzle, and a tubular waveguide extending from the radio frequency transponder to the horn via one of the plurality of case apertures, wherein the flame sensor is configured to perform flame and flow field diagnostics.

[0005] In addition to one or more aspects of the combustor, or as an alternate, the flame sensor is configured to determine the presence of the flame.

[0006] In addition to one or more aspects of the combustor, or as an alternate, the flame sensor is configured to control a polarization of a transmission from the radio frequency transponder, to obtain data for a fluid dynamic analysis of a flow field of the fuel for imaging the flow field.

[0007] In addition to one or more aspects of the combustor, or as an alternate, the flame sensor is configured to control a waveform mode from the radio frequency transponder to provide for detecting different portions of the flame, to perform flame and flow field diagnostics in two or three dimensions.

[0008] In addition to one or more aspects of the combustor, or as an alternate, the flame sensor is configured to measure a reflective intensity of the flame to determine an intensity of combustion.

[0009] In addition to one or more aspects of the combustor, or as an alternate, the waveguide is one of: a transverse electromagnetic transmission line; a hollow tube; a dielectrically filled tube; and an air filled tube.

[0010] In addition to one or more aspects of the combustor, or as an alternate, the horn includes a lens formed of one or more of a dielectric and a metal.

[0011] Further disclosed is a gas turbine engine including: a combustor that includes: a combustor case defining a plurality of case apertures; a liner within the combustor case defining a combustion

zone and liner apertures through which an airflow flows into the combustion zone; a fuel injector having a fuel channel extending through a first case aperture and the liner, and the fuel channel has a nozzle at the combustion zone through which fuel is injected, to produce a combustible mixture with the airflow; an igniter extending through a second case aperture and the liner for igniting the combustible mixture and providing a flame at the nozzle; and a flame sensor including: a radio frequency transponder, comprising a transmitter-receiver pair, located exterior to the combustor case; a horn disposed in the fuel nozzle, and a tubular waveguide extending from the radio frequency transponder to the horn via one of the plurality of case apertures, wherein the flame sensor is configured to perform flame and flow field diagnostics.
[0012] In addition to one or more aspects of the engine, or as an alternate, the flame sensor is configured to determine the presence of the flame.
[0013] In addition to one or more aspects of the engine, or as an alternate, the flame sensor is configured to control a polarization of a transmission, to obtain data for a fluid dynamic analysis of a flow field of the fuel for imaging the flow field.
[0014] In addition to one or more aspects of the engine, or as an alternate, the flame sensor is configured to control a waveform mode to provide for detecting different portions of the flame, whereby the flame sensor performs flame and flow field diagnostics in two or three dimensions.
[0015] In addition to one or more aspects of the engine, or as an alternate, the flame sensor is configured to measure a reflective intensity of the flame to determine an intensity of combustion.
[0016] In addition to one or more aspects of the engine, or as an alternate, the waveguide is one of: a transverse electromagnetic transmission line; a hollow tube; a dielectrically filled tube; and an air filled tube.
[0017] In addition to one or more aspects of the engine, or as an alternate, the horn includes a lens formed of one or more of a dielectric and a metal.
[0018] In addition to one or more aspects of the engine, or as an alternate, the engine includes: an inlet; a compressor downstream of the inlet; a turbine downstream of the compressor; and an exhaust downstream of the turbine, wherein the combustor is between the compressor and the turbine.
[0019] Further disclosed is a method of performing flame and flow field diagnostics in a combustor of a gas turbine engine, the method including: directing an airflow into a combustion zone of the combustor; directing fuel, via a fuel injector channel and a fuel nozzle, into the combustion zone to provide a combustion mixture with the airflow; igniting the combustion mixture to provide the flame; and performing flame and flow field diagnostics with a flame sensor via a radio frequency transponder comprising a transmitter-receiver pair, a horn in the fuel nozzle, and a tubular waveguide extending between the radio frequency transponder and the horn.
[0020] In addition to one or more aspects of the method, or as an alternate, the method includes determining with the flame sensor the presence of the flame.
[0021] In addition to one or more aspects of the method, or as an alternate, the method includes controlling a polarization of a transmission from the radio frequency transponder, to obtain data for a fluid dynamic analysis of a flow field of the fuel for imaging the flow field.
[0022] In addition to one or more aspects of the method, or as an alternate, the method includes controlling a waveform mode from the radio frequency transponder to provide for detecting different portions of the flame to perform flame and flow field diagnostics in two or three dimensions.
[0023] In addition to one or more aspects of the method, or as an alternate, the method includes measuring with the flame sensor a reflective intensity of the flame to determine an intensity of combustion.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

[0025] FIG. **1** is a partial cross-sectional view of a gas turbine engine;

[0026] FIG. **2**A shows details of a combustor configured for performing flame and flow field diagnostics in a combustor of a gas turbine engine, with a guide wire and horn antenna of the sensor in a first configuration;

[0027] FIG. **2**B the combustor configuration of FIG. **2**A, with the guide wire and horn antenna of the sensor in a second configuration;

[0028] FIG. **2**C the combustor configuration of FIG. **2**A, with the guide wire and horn antenna of the sensor in a third configuration; and

[0029] FIG. **3** is a flowchart showing a method of performing flame and flow field diagnostics in a combustor of a gas turbine engine.

DETAILED DESCRIPTION

[0030] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0031] FIG. **1** schematically illustrates a gas turbine engine **20**. The gas turbine engine **20** is disclosed herein as a two-spool turbofan that generally incorporates a fan section **22**, a compressor section **24**, a combustor section **26** and a turbine section **28**. Alternative engines might include other systems or features. The fan section **22** drives air along a bypass flow path B in a bypass duct, while the compressor section **24** drives air along a core flow path C for compression and communication into the combustor section **26** then expansion through the turbine section **28**. Although depicted as a two-spool turbofan gas turbine engine in the disclosed non-limiting embodiment, it should be understood that the concepts described herein are not limited to use with two-spool turbofans as the teachings may be applied to other types of turbine engines including three-spool architectures.

[0032] The exemplary engine **20** generally includes a low speed spool **30** and a high speed spool **32** mounted for rotation about an engine central longitudinal axis A relative to an engine static structure **36** via several bearing systems **38**. It should be understood that various bearing systems **38** at various locations may alternatively or additionally be provided, and the location of bearing systems **38** may be varied as appropriate to the application.

[0033] The low speed spool **30** generally includes an inner shaft **40** that interconnects a fan **42**, a low pressure compressor **44** and a low pressure turbine **46**. The inner shaft **40** is connected to the fan **42** through a speed change mechanism, which in exemplary gas turbine engine **20** is illustrated as a geared architecture **48** to drive the fan **42** at a lower speed than the low speed spool **30**. The high speed spool **32** includes an outer shaft **50** that interconnects a high pressure compressor **52** and high pressure turbine **54**. A combustor **56** is arranged in exemplary gas turbine **20** between the high pressure compressor **52** and the high pressure turbine **54**. An engine static structure **36** is arranged generally between the high pressure turbine **54** and the low pressure turbine **46**. The engine static structure **36** further supports bearing systems **38** in the turbine section **28**. The inner shaft **40** and the outer shaft **50** are concentric and rotate via bearing systems **38** about the engine central longitudinal axis A which is collinear with their longitudinal axes.

[0034] The core airflow is compressed by the low pressure compressor **44** then the high pressure compressor **52**, mixed and burned with fuel in the combustor **56**, then expanded over the high pressure turbine **54** and low pressure turbine **46**. The turbines **46**, **54** rotationally drive the respective low speed spool **30** and high speed spool **32** in response to the expansion. It will be appreciated that each of the positions of the fan section **22**, compressor section **24**, combustor section **26**, turbine section **28**, and fan drive gear system **48** may be varied. For example, gear system **48** may be located aft of combustor section **26** or even aft of turbine section **28**, and fan section **22** may be positioned forward or aft of the location of gear system **48**.

[0035] The engine **20** in one example is a high-bypass geared aircraft engine. The geared architecture **48** may be an epicycle gear train, such as a planetary gear system or other gear system. It should be understood, however, that the above parameters are only exemplary of one embodiment of a geared architecture engine and that the present disclosure is applicable to other gas turbine engines including direct drive turbofans.

[0036] A significant amount of thrust is provided by the bypass flow B due to the high bypass ratio.

[0037] Turning to FIGS. **2**A-**2**C, a diffuser **90** directs air to the combustor **56** from the high-pressure compressor **52**. The combustor **56** includes a case **100** that defines a plurality of case apertures, generally reference as **105** and discussed in greater detail below. The diffuser **90** is located at a forward end of the combustor case **100**. A liner **110** is within the case **100** and the liner **110** surrounds a combustion zone **120**. The combustor **56** includes a dome **140** and a snout **150**, which is an extension of the dome **140**, and a swirler **160**. The snout **150** is an air splitter, separating airflows from the diffuser **90**.

[0038] The combustor **56** includes a fuel injector **170** having a fuel injector channel **180** that extends through a first case aperture **105**A. The fuel channel **180** has a nozzle **190** (or opening) that opens into the combustion zone **120** via the dome **140**. The nozzle **190** is surrounded by the swirler **160** and snout **150**. Air flows through the dome **140** and swirler **160** as it enters the combustion zone **120** to mix with the fuel from the fuel injector **170** and form a combustible mixture. Liner apertures, generally referenced as **200**, include for example three liner apertures **200**A, **200**B, **200**C that direct air into the combustion zone **120** to cool and condition the combustion products. An igniter **210** extends thorough the case **100** via second case aperture **105**B for igniting the combustible mixture and providing a flame.

[0039] According to an embodiment, a flame sensor **220** is provided. The flame sensor **220** includes a radio frequency (RF) transponder (for simplicity, a transponder) **230**. The transponder **230** includes a transmitter-receiver pair. The transponder **230** is operationally coupled to a controller **235**, which may be an engine controller or other controller. The transponder may operate in frequencies between the GHz to THz, and more specifically within the range 1 GHz and 140 GHz, in time partition transmission and reception, as discussed in greater detail below. A tubular waveguide **240** extends from the Transponder **230** to a microwave horn antenna (for simplicity, a horn) **250** in the nozzle **190** to sense conditions of the flame. In one embodiment, the waveguide **240** is a transverse electromagnetic transmission line, a hollow tube, a dielectrically filled tube or an air filled tube. In one embodiment, the horn **250** includes a lens **255** formed of one or more of a dielectric and a metal. Specifically, the waveguide **240** can be a tubular device, or can be a dielectric waveguide, or some combination.

[0040] The waveguide **240** may be provided in various configurations, e.g., along various paths, between the transponder **230** and the horn **250**. In a first configuration of the waveguide **240** (FIG. **2**A), the waveguide **240** may extend to the nozzle **190** via the first case aperture **105**A, e.g., within the fuel channel **180**. In one embodiment, a cavity **195** (schematically shown) is provided in and through the fuel nozzle **190** to accommodate the horn, one cavity for each fuel nozzle. With this configuration, performance of the fuel nozzles can be compared, e.g., by comparing an absolute and relative fuel nozzle to all the other fuel nozzles. This configuration would enable the use of feedback control on the fuel nozzles to improve pattern factor and thus improve engine performance.

[0041] In a second configuration of the waveguide **240** (FIG. **2**B), the waveguide **240** may extend to the nozzle **190** via the second case aperture **105**B, e.g., adjacent to the igniter **210**. In a third configuration of the waveguide **240** (FIG. **2**C), the waveguide **240** may extend to the nozzle **190** via a third case aperture **105**C that is spaced apart from the first and second case apertures **105**A, **105**B.

[0042] That is, the waveguide **240** could be contained within the igniter **210**, aligned along the length, which allows orthogonal imaging of the flame, allowing characterization of the entire flame front. Aligning the waveguide **240** along the nozzle **190** allows for lengthwise imaging and thus requires a smaller field of view and will be more compact. The different configurations of the waveguide **240** are not intended in limiting the configuration of the embodiments. It is to be appreciated that extending the waveguide through the first or second apertures **105**A, **105**B avoids having to form the third aperture **105**C in the combustor case **100**, which may be thermally efficient.

[0043] In one embodiment, the combustor **56** has a plurality of fuel injectors **170** with a corresponding plurality of fuel channels **180** and related nozzles **190**. A plurality of the horns **250** may be provided, with one of the horns **250** being disposed in each of the nozzles **190**. A corresponding plurality of waveguides **240** may extend from the same transponder **230**, or optionally multiple transponders **230**, to respective ones of the horns **250**. The different waveguides may each couple with the respective horns **250** via one of the configurations (FIGS. **2**A-**2**C) disclosed herein.

[0044] In one embodiment, the flame sensor **220** may be configured to control a transmission frequency from the Transponder **230**. This enables determining one or more of a density, a mobility, and a temperature of the flame.

[0045] In one embodiment, the flame sensor **220** may be configured to control a polarization of the transmission from the Transponder **230**. This enables obtaining data for a fluid dynamic analysis of the flow field of the fuel for imaging the flow field. This analysis enables, e.g., identifying when an impediment is within the fuel channel **180**.

[0046] In one embodiment, the flame sensor **220** may be configured to control a waveform mode from the transponder **230**. This provides for detecting different portions of the flame, to perform flame and flow field diagnostics in two or three dimensions.

[0047] In one embodiment, the flame sensor **220** may be configured to measure a reflective intensity of the flame. This enables the determination of an intensity of combustion.

[0048] As indicated, in one embodiment, a plurality of waveguides **240** are coupled between the transponder **230** and a plurality of horns **250** that are located in different ones of a plurality of the nozzles **190**. In this embodiment, the flame sensor **220** may be configured to multiplex signals through the different waveguides **240**. This enables performing flame and flow field diagnostics at each of the nozzles **190**.

[0049] With the disclosed embodiments, the plasma nature of flames is exploited to diagnose the presence and quality of a flame emanating from combustion found in the combustor **56**. Combustion creates a mixture a electrically conductive plasma that acts to reflect radio frequency waves similar to a sheet of metal. Electromagnetic radiation can be used to sense the presence or absence of a flame, thereby enabling a pattern factor determination for the flame.

[0050] The embodiments provide a radio frequency transmission and receiving transponder **230** operating at frequencies between the GHz to THz. The transponder **230** operating in this range creates radio frequency energy that impinges upon the flame, if it is present, with some portion of the incident energy reflected back, based on the volumetric extent of the flame. If the flame is not present, e.g., due to a blockage in the fuel channel **180**, then the reflected signal is near zero, indicating a flame-out situation. By varying the frequency, polarization, directions by choice of mode shapes, and intensity of the electromagnetic radiation, the extent and intensity of the flame can be determined. As the detecting (or interrogation) can occur in nanoseconds, multiple flames from several of the nozzles **190** may be analyzed using the same flame sensor **220**. Further, typically a forward signal and reflected signal may be characterized by the system scattering parameters (sometimes referred to as S parameters). However, the disclosed sensor **220** provides for other detection schemes including reflection coefficient schemes, standing wave ration schemes, as nonlimiting examples. For example, the value of S**11**, which indicates the backscattered radiation, will depend upon whether the flame is present and its spatial extent. It should be appreciated that a fully reflective surface has an S**11** value of 0 dB, while a fully transmissive system has an S**11** value of less than −50 bB or more, though these values are typically ideal and not obtained in practice.

[0051] Turning to FIG. **3**, a flowchart shows a method of performing flame and flow field diagnostics in a combustor of a gas turbine engine. As shown in block **310** the method includes directing an airflow into the combustion zone **120** of the combustor **56**. As shown in block **320** the method includes directing fuel, via the fuel channel **180** and the fuel nozzle **190**, into the combustion zone **120** to provide a combustion mixture with the airflow. As shown in block **330** the method includes igniting the combustion mixture to provide the flame.

[0052] As shown in block **340** the method includes performing flame and flow field diagnostics with a flame sensor **220** via the transponder **230**, a horn **250** in the fuel nozzle **190**, and a tubular waveguide **240** extending between the transponder **230** and the horn **250**. As shown in block **350** the method includes controlling a transmission frequency from the transponder **220** to determine one or more of a density, a mobility, and a temperature of the flame. As shown in block **360** the method includes controlling a polarization of the transmission from the transponder **220**, to obtain data for a fluid dynamic analysis of the flow field of the fuel for imaging the flow field. As shown in block **370**, the method includes controlling a waveform mode from the transponder **220** to provide for the detecting of different portions of the flame to perform flame and flow field diagnostics in two or three dimensions. As shown in block **380** the method includes measuring with the flame sensor **220** a reflective intensity of the flame to determine an intensity of combustion. In other words, the flame sensor **220** can determine not only the presence of the flame, but provide diagnostics of it: intensity, spatial extent, temperature, % combustion, flow field dynamics, etc.

[0053] As indicated, the sensor **220** is configured for controlling output polarization. Selecting the electromagnetic polarization allows the impinging wave to determine the flow stream of the charge carriers and therefore allows both fluid dynamic analysis and the ability to image the flow fields. The sensor **220** is configured for controlling output frequency. By varying frequency, the sensor **220** can determine carrier density, mobility, and temperature of the flame, which is useful in understanding flame dynamics. The sensor **220** is configured for controlling an output mode. Mode shape allows the detecting of various portions of the flame, thereby enabling performing of flame and flow field diagnostics in two or three dimensions, e.g., to provide a flame shape. With the transponder **230**, typically a forward signal and reflected signal are characterized by the system scattering parameters (sometimes referred to as S parameters). However, the sensor **220** provides for other detection schemes including reflection coefficient schemes, and standing wave ration schemes, as nonlimiting examples. The sensor **220** is configured for measuring reflective intensity. By measuring the reflected intensity, the sensor **220** can determine the degree of combustion.

[0054] With the use of the horn **250**, the sensor **220** can be used as a point sensor for minimal diagnostics. The sensor **220** is configured for multiplexing. That is, a single or multiple transponders constituting a transmitter and receiver (Tx/Rx) can enable multi-burner detecting (or sensing), to reduce costs, size, weight, and power requirements of the sensor **220**. The sensor **220** can operate in continuous wave (CW) or pulsed power with time allocations to sensing position of the flame and to allow the same waveguide **240** to be used to both send and receive diagnostic signals. The sensor **220** is configured for controlling the output frequency. The interrogation frequency of interest is from 1 GHz up to 1 THz, and more specifically within the range 10 GHz and 140 GHz. The waveguide **240** may include a stripline, it may be hollow, it may have a dielectric fill, air fill, it may be circular, rectangular, etc. The horn **250** also can be circular, rectangular, etc. The horn **250** can be optionally fitted with a lens **255**, which can be made of dielectric, metal or the combination of metal and dielectric.

[0055] In sum, the embodiments utilize GHz to THz based radio frequency reflectometry to detect and image a flame to determine the pattern factor from a fuel nozzle **190**. The embodiments provide for varying polarization, mode shape, frequency and phase of an incident radio frequency

signal to spatially detect a combustor flame. The embodiments measure the reflected radiation from the flame in time partition transmission and reception. The embodiments use a radio frequency transponder **230** placed remote to the region of ignition, e.g., the combustion zone **120**, with waveguided transmissions and reception. In addition, the utilization of a radio frequency solution enables the sensing to occur beyond line of sight, e.g., which might occur with an optical sensor solution.
[0056] The term “about” is intended to include the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application.
[0057] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the present disclosure. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, element components, and/or groups thereof.
[0058] While the present disclosure has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the present disclosure. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the essential scope thereof. Therefore, it is intended that the present disclosure not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this present disclosure, but that the present disclosure will include all embodiments falling within the scope of the claims.

Claims

1. A combustor of a gas turbine engine, comprising: a combustor case defining a plurality of case apertures; a liner within the combustor case defining a combustion zone and liner apertures through which an airflow flows into the combustion zone; a fuel injector having a fuel channel extending through a first case aperture and the liner, and the fuel channel has a nozzle at the combustion zone through which fuel is injected, to produce a combustible mixture with the airflow; an igniter extending through a second case aperture and the liner for igniting the combustible mixture and providing a flame at the nozzle; and a flame sensor including: a radio frequency transponder, comprising a transmitter-receiver pair, located exterior to the combustor case; a horn antenna disposed in the fuel nozzle, and a tubular waveguide extending from the radio frequency transponder to the horn via one of the plurality of case apertures, wherein the flame sensor is configured to perform flame and flow field diagnostics.
2. The combustor of claim 1, wherein: the flame sensor is configured to determine the presence of the flame.
3. The combustor of claim 1, wherein: the flame sensor is configured to control a polarization of a transmission from the radio frequency transponder, to obtain data for a fluid dynamic analysis of a flow field of the fuel for imaging the flow field.
4. The combustor of claim 1, wherein: the flame sensor is configured to control a waveform mode from the radio frequency transponder to provide for detecting different portions of the flame, to perform flame and flow field diagnostics in two or three dimensions.
5. The combustor of claim 1, wherein: the flame sensor is configured to measure a reflective intensity of the flame to determine an intensity of combustion.
6. The combustor of claim 1, wherein: the waveguide is one of: a transverse electromagnetic transmission line; a hollow tube; a dielectrically filled tube; and an air filled tube.
7. The combustor of claim 1, wherein: the horn includes a lens formed of one or more of a

dielectric and a metal.

8. A gas turbine engine comprising: a combustor that includes: a combustor case defining a plurality of case apertures; a liner within the combustor case defining a combustion zone and liner apertures through which an airflow flows into the combustion zone; a fuel injector having a fuel channel extending through a first case aperture and the liner, and the fuel channel has a nozzle at the combustion zone through which fuel is injected, to produce a combustible mixture with the airflow; an igniter extending through a second case aperture and the liner for igniting the combustible mixture and providing a flame at the nozzle; and a flame sensor including: a radio frequency transponder, comprising a transmitter-receiver pair, located exterior to the combustor case; a horn disposed in the fuel nozzle, and a tubular waveguide extending from the radio frequency transponder to the horn via one of the plurality of case apertures, wherein the flame sensor is configured to perform flame and flow field diagnostics.

9. The gas turbine engine of claim 8, wherein: the flame sensor is configured to determine the presence of the flame.

10. The gas turbine engine of claim 8, wherein: the flame sensor is configured to control a polarization of a transmission, to obtain data for a fluid dynamic analysis of a flow field of the fuel for imaging the flow field.

11. The gas turbine engine of claim 8, wherein: the flame sensor is configured to control a waveform mode to provide for detecting different portions of the flame, whereby the flame sensor performs flame and flow field diagnostics in two or three dimensions.

12. The gas turbine engine of claim 8, wherein: the flame sensor is configured to measure a reflective intensity of the flame to determine an intensity of combustion.

13. The gas turbine engine of claim 8, wherein: the waveguide is one of: a transverse electromagnetic transmission line; a hollow tube; a dielectrically filled tube; and an air filled tube.

14. The gas turbine engine of claim 8, wherein: the horn includes a lens formed of one or more of a dielectric and a metal.

15. The gas turbine engine of claim 8, further comprising: an inlet; a compressor downstream of the inlet; a turbine downstream of the compressor; and an exhaust downstream of the turbine, wherein the combustor is between the compressor and the turbine.

16. A method of performing flame and flow field diagnostics in a combustor of a gas turbine engine, the method comprising: directing an airflow into a combustion zone of the combustor; directing fuel, via a fuel injector channel and a fuel nozzle, into the combustion zone to provide a combustion mixture with the airflow; igniting the combustion mixture to provide the flame; and performing flame and flow field diagnostics with a flame sensor via a radio frequency transponder comprising a transmitter-receiver pair, a horn in the fuel nozzle, and a tubular waveguide extending between the radio frequency transponder and the horn.

17. The method of claim 16, further comprising determining with the flame sensor the presence of the flame.

18. The method of claim 16, further comprising controlling a polarization of a transmission from the radio frequency transponder, to obtain data for a fluid dynamic analysis of a flow field of the fuel for imaging the flow field.

19. The method of claim 16, further comprising controlling a waveform mode from the radio frequency transponder to provide for detecting different portions of the flame to perform flame and flow field diagnostics in two or three dimensions.

20. The method of claim 16, further comprising measuring with the flame sensor a reflective intensity of the flame to determine an intensity of combustion.