Transceiver System for Audio Alarming Using Radio FM Stations

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***Abstract*—Emergency alert systems is required in a modern society. It is composed by warning messages delivered to the nation public in consequence of imminent threats to the public safety. An emergency alert message system over mobile phones is already implemented in Portugal. In this paper, we propose an innovative voice-based emergency alert system. Our solution makes use of local radio stations to deliver the voice alert messages to the vehicle driver.**

Keywords*— *Emergency, Forest Fires Radio, FM, MPX, RDS

I. INTRODUCTION

After the great wave of forest fires that devastated Portugal in 2017 and caused over sixty fatalities, it became imperative to develop an alarm system that could warn drivers about the location of fires and which roads to avoid. This can prevent people from being surrounded by the flames and losing their lives [1].

An overview representation of the whole system is presented in Fig. 1. Each local FM station will integrate one Firetec Switch, all of them commanded by a central Manager. The full system will include optical fiber sensor with the capability of detection high temperatures. The part addressed in this paper is the “Firetec Switch” block. Either the audio signals or the multiplexed signal (MPX) to be broadcasted are going through the Firetec Switch and fed into the FM modulator.

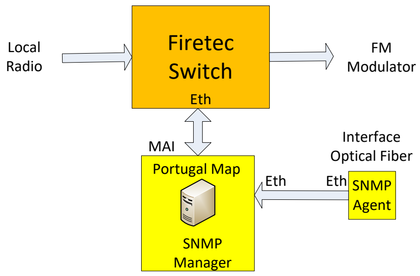

Fig. 1. Solution overview.

II. FM RADIO SYSTEM

A. *FM Modulation*

The radio transmission uses a frequency modulation scheme which is a form of analog angle modulation in which the baseband information carrying signal, typically called the information signal, varies the frequency of a carrier wave. This is the main modulation type used by broadcasting radio stations nowadays.

A general representation of a typical FM transmission is presented in Fig. 2.

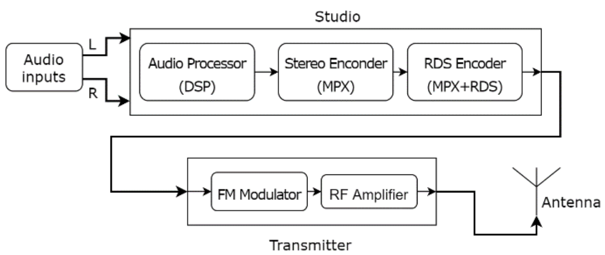

Fig. 2. Typical FM radio broadcasting system.

It is possible to see that the inputs to this transmission system are audio left and right channels. They go through a box denominated studio which contains the Digital Signal Processor (DSP) that processes the audio signals. Next, there is a Stereo Encoder (MPX) which multiplexes the audio channels on a determined carrier, that of 19kHz. After the encoding, the signal has yet to go through an RDS encoder that will be further detailed in the next section. The output signal of the studio will finally go to the FM transmitter/modulator. Finally, the modulated signal is amplified and then fed into the antenna, which radiates the radio signal [2].

The Stereo Encoder receives the audio channels processed and internally there are a sum and a subtraction modules of those channels. The subtraction of the left and right channels is modulated with a 38KHz subcarrier using an Amplitude Modulation, in other words, Double Sideband Suppressed Carrier modulation.

To keep the FM receiver tracked at 38KHz subcarrier, a 19KHz pilot tone is transmitted which is half of that subcarrier value.

The output signal of the MPX block consists of the subtraction of the left and right channels, the pilot tone, the sum of the left and right channels and may also contain the RDS carrier frequency, 57KHz. A representation of full spectrum is shown in Fig. 3 [2].

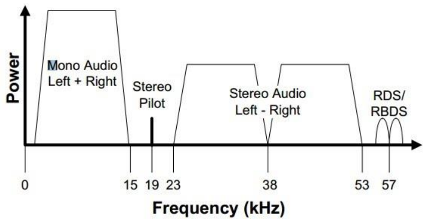

Fig. 3. FM MPX frequency spectrum [2].

B. RDS Specifications

Although most of the transmitted signals are analog, FM radio stations can also transmit digital data known as Radio Data System (RDS) in Europe and Radio Broadcast Data System (RBDS) in the USA. Developed in the seventies and early eighties, the RDS is a communication protocol which integrates several digital information, such as the radio station identification, program information, time, among others. This information is transmitted at 1187.5 bits per second at 57KHz subcarrier, exactly the third harmonic of the 19KHz pilot signal, as mentioned in the previous sub-section [3].

The RDS allows the station to transmit the Programme Service (PS) name which makes the receiver to tune to a radio station by its name. Another important feature is the transmission of the Programme Identification (PI) code. Through this code, the receiver is able to automatically switch to the another available frequency with higher power level for the specific radio station. Without this functionality, the user would need to manually and constantly tune the receiver to another frequency when the power level of the previous frequency decreases significantly. The automatic frequency support is achieved through the Alternative list of Frequencies (AF), a mechanism usually used by national FM radio operators.

Table I summaries the RDS information fields together with its respective definition.

TABLE I. RDS INFORMATION FIELDS

Information fields	Definition
PS (Programme Service)	Eight-character static display that represents the station identity name
PI (Programme Identification)	Unique 4-character hexadecimal code that identifies the station (national, regional)
RT (Radio text)	64 character free-form text message
CT (Clock Time and date)	Can synchronize a clock in the receiver or the main clock in the car
AF (Alternative Frequencies list)	This provides the receiver with a list of frequencies that allows the receiver to re-tune to a different frequency providing same station

III. ARCHITECTURE

In this section, we describe our proposed engineering solution to implement the switch module as mentioned in Section I. To come up with a solution, there were two different approaches considered. The first one focused merely on switching the audio signal that was sent to the FM station broadcasting system. The second approach already incorporated the audio processing which generates an MPX signal that also contains the RDS information to be broadcasted. The latter would allow for a more complete solution that could send text messages to the receivers as well as a list of frequencies to support frequency retuning in case of signal loss as discussed before. The first solution is acceptable in the case of a local radio station which does not use MPX+RDS.

A. Audio Switching

As referred above, the first approach to support our solution was simply through switching the audio source that feeds the DAC of the radio broadcasting system. The "normal state" of the output of the switching device is the regular/live radio signal. In case of an alert situation, the switching device will receive a message from the server (Manager) redirecting it through the switch and afterwards into the output. Thus, an alarm message that will be broadcasted through the FM radio station system.

B. MPX + RDS Switching

In case of radio local station with MPX+RDS, we designed another solution where the switching functionality is done at a later stage, that of MPX+RDS level. Beyond of deliver to the local FM station, an MPX+RDS switching module, we also need include a RDS encoder to support the AF concept. Therefore, the local radio stations close the affected (fire location) region have to change from their original PI to a common PI. Fig. 4 shows a block diagram of this solution. To summarize, it is based on using a server (manager) from where the alarm message and the RDS commands are generated and delivered to the local stations.

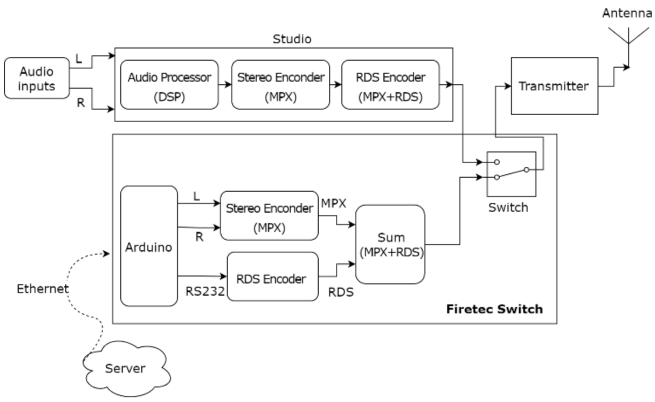

Fig. 4. Firetec MPX+RDS switching solution.

Communication between the server and the local radio stations is carried out via Ethernet communication through a socket/IP. This information is processed by an Arduino microcontroller, which already processes the audio that will be the input of the MPX encoder. After MPX encoding, the signal will go to the RDS encoder where the RDS data will be added to the MPX signal. RDS messages are sent directly from Arduino to the RDS encoder via RS232 communication protocol.

As can be seen in Fig. 4, both the Firetec Switch signal, which serves to identify the regular radio broadcast, and the alarm message signal enter a switching block where a decision will be made depending on whether there is an alarm situation or not.

C. Block Diagrams

This section, we focuses on discussing further the Firetec Switch and its relationship with other modules. To understand the integration of the Firetec Switch, an example of the external connections is shown in Fig. 5.

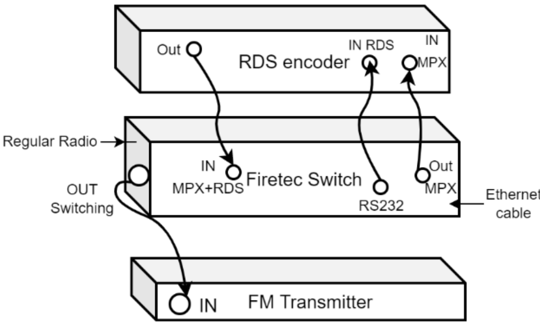

Fig. 5. Example of the external conections.

It should be noted that in this prototype, the RDS encoder is located in a box/block apart from the Firetec Switch due to the fact that, for a simpler implementation, it was decided to purchase an equipment that encodes RDS itself directly. This equipment, the P232U RDS Encoder [4], has the particularity of supporting required commands, namely AF, PS, PI, RT and even Enhanced Other Networks (EON).

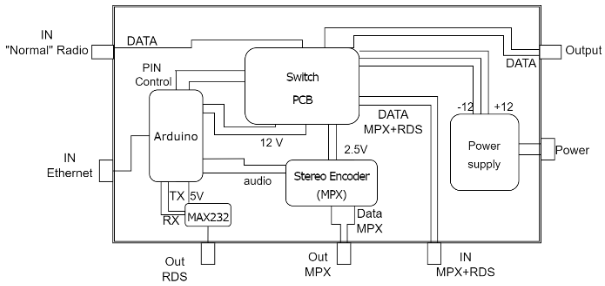

Fig. 6. Example of the internal Firetec conections.

Regarding the internal connections of the developed Firetec Switct, it is presented in Fig. 6, the high-level block diagram of the box. In short, we have as inputs the regular radio broadcast which is nothing more than the radio signal modulated with the MPX and the RDS of the local FM radio station. This signal will go to the "swicth PCB" circuit, which will be better detailed later in this document. Another input is the Ethernet input which, as already mentioned, is connected to the Arduino microcontroller, which will process all the data related to the RDS commands and also process the alert audio message. The microcontroller will also receive a command to change the switch included in the "switch PCB" and connect its output to the alert message. The "switch PCB" circuit is then responsible for switching between the regular radio broadcast and the alert message signal. This block is also responsible for managing the power supplies needed to power both the MPX encoder and the Arduino.

"Power supply" block is intended to convert the 240VAC to a DC voltage. The block responsible for converting TTL voltages to RS232 voltages is the block called "MAX232" in Fig. 6.

The Stereo encoder (MPX) circuit (NEW JAPAN RADIO-NJM2035d chip) modulates the audio signal and sends it to the RDS encoder. The signal coming from the RDS encoder returns back to the Firetec Switch and connects to the switch PCB. The signal that will come out of our Firetec Switch is either the regular radio broadcast or the alert message. This signal enters the FM transmitter to be modulated and transmitted.

IV. MEASUREMENTS

In this section, we describe some measurements in order to be sure all circuits and protocols fulfil the requirements. Firstly, there were a few tests made related to the switching part named as "Switch PCB". With these tests, it was mainly intended to verify the proper switching of two different signals represented by sine waves with different frequencies.

The first wave, with a frequency of 1 kHz is represented in yellow, illustrating the warning signal and the second one in blue, with a frequency of 500 Hz representing the regular radio signal as seen in the Fig. 7.

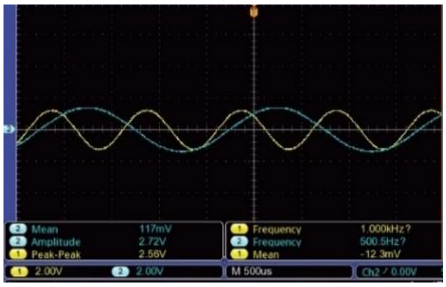

Fig. 7. Sine waves used in tests.

As the objective is to only issue the alert under a fire situation, most of the time it will broadcast the radio station program. To control the switching, the appropriate pin is placed at logic zero, so it should output the normal radio signal. The logic level will change to one only when there is an alert, which causes the output to switch to the alarm message.

The test carried out consisted of applying both logic level zero (0 V, LOW) and logic level one (5 V, HIGH) to the control pin, represented in the yellow signal in Figure 8 and Figure 9 respectively. When the control pin is at 0 V, the output, represented in the blue wave, is on the regular radio signal represented by the 500 Hz sine. On the other hand, if the control pin is at 5 V, the output switches to the 1 kHz wave.

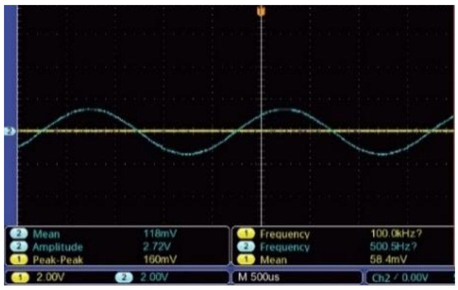

Fig. 8. Control pin LOW (yellow) and switch output (blue).

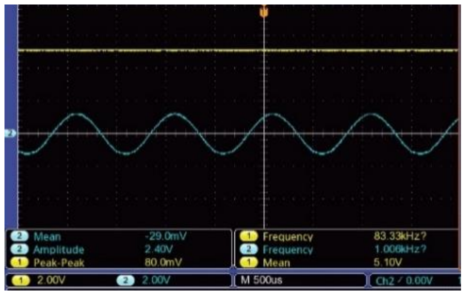

Fig. 9. Control pin HIGH (yellow) and switch output (blue).

Another test was performed, using the oscilloscope, to check the waveform of the RDS signal. As an RDS waveform reference, the signal shown in Fig. 10 was considered.

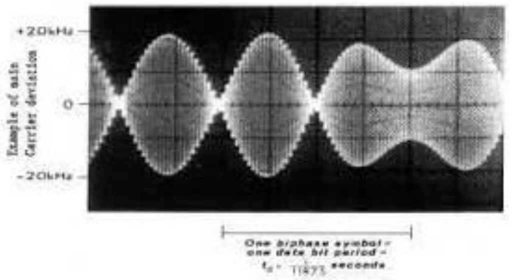

Fig. 10. Example of na RDS capture through an oscilloscope [3].

Using an RDS encoder as part of the system, the waveform presented in Fig. 11 was obtained which is clearly similar to the standardized RDS signal.

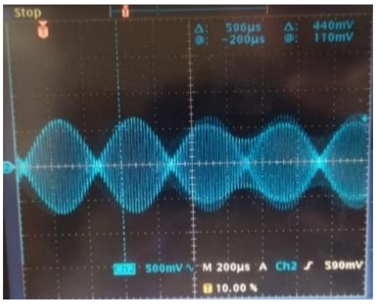

Fig. 11. RDS signal obtained in the laboratory with the osciloscope.

The tests related to the MPX signal were essentially divided in two parts, being the first one to allow the identification of the 19 kHz pilot signal and the 38 kHz component, through the oscilloscope. The second test consisted in the visualization of the MPX signal spectrum through an FM analyzer. Both the 19 kHz and the 38 kHz components are shown in Fig. 12.

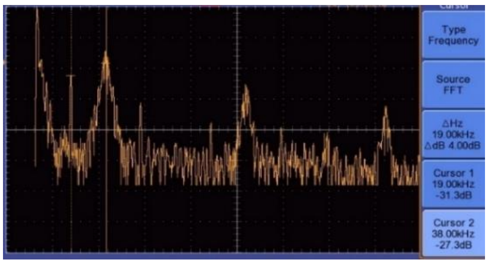

Fig. 12. Representation on the oscilloscope of the pilot tone and 38kHz component obtained in the laboratory from the MPX signal.

The FM analyzer was used to compare the MPX signal spectrum of a local FM radio station and the MPX signal spectrum of the alarm system FM broadcast, to compare whether the data and values obtained were among the typical range. Thus, in Table II, a set of determining factors to evaluate the quality of the FM transmission are the overall frequency deviation (peak frequency deviation), ΔF, Pilot deviation, RDS deviation and Modulation power (MPX power, Pm). Each of these parameters has a certain acceptable range, to which their values were compared between the local radio "Terra Nova" and our proposed solution (Firetec Switch).

In terms of visualization, the FM analyzer [5] provides several measurements namely the MPX spectrum, RDS messages, among other features. This spectrum can be seen in Figures 13 and 14, which depict the FM radio signal from "Terra Nova" and the emission of an alarm message in the laboratory, respectively.

TABLE II. DEVIATION VALUES OF TWO DIFFERENT BROADCASTS

Deviation	Range	Terra Nova	Alert
[ΔF]	<75 kHz	70.5 kHz	17.1 kHz
Pilot deviation	[6.0, 7.5] kHz	7.0 kHz	5.9 kHz
RDS deviation	[1.0, 7.5] kHz	2.5 KHz	1.7 KHz
Modulation power	[+5, +6] dBr	5.3 dBr	-9.2 dBr

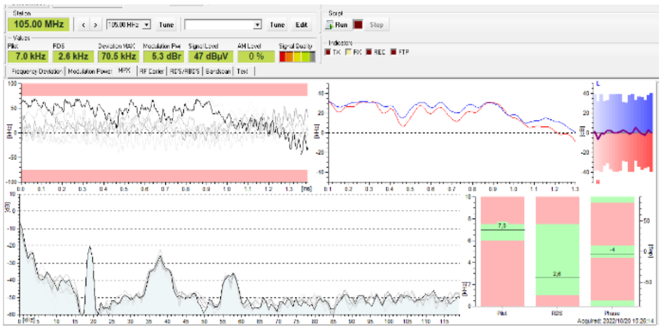

Fig. 13. MPX spectrum of local radio Terra Nova.

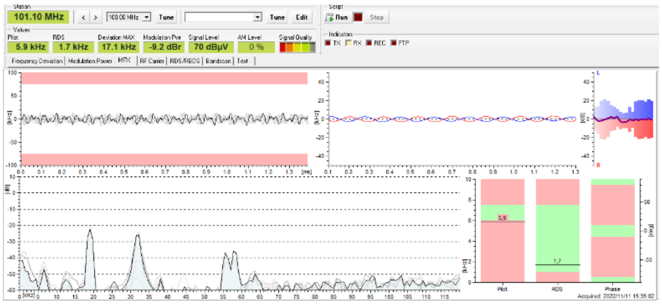

Fig. 14. MPX spectrum of na alert audio laboratory broadcast.

V. CONCLUSION

In this paper, we present an alert system composed by hardware and software modules. We have tested our proposed solutions and the demonstrator consists of two full units supporting AF RDS functionality is available. This research and development work answer a clear society challenge.

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