Deployment of Microstrip Patch Antenna in FDMA Communication System

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Abstract:

A low profile microstrip patch antenna is designed and tested for wireless FDMA communication applications. The design involves the Inset feeding technique and substrate FR4 which is dielectric in nature. The slotted patch is designed using CST and simulated results show that patch resonates in frequency range of 2-3 GHz, suitable for GSM, LTE etc, with reasonable antenna characteristics. A FDMA wireless communication system (CS) is designed with transmitter, receiver and channel also by exploiting the antenna with corresponding coding and modulation techniques. This CS plots the spectra of sample signals at every stage from transmission till receiving them using Matlab. The results are displayed in picture and audio formats.

Keywords: Inset feed, Microstrip patch antenna, FDMA, Signals Spectra, coding, modulation, etc.

Introduction:

Any communication system is formed of three main components: a transmitter, a channel and a receiver. The information source sends the message signal via the transmitter and the signal is conducted to a receiver via a channel where it can be overlapped with noise. The signal is received and fed to the user of information. The transmitter is mainly a cascade of a source encoder, a channel encoder and a modulator while the receiver is a cascade of a demodulator, a channel decoder and a source decoder.

In this paper, a conventional Frequency division multiplexing (FDM) is used. Using FDM to allow multiple users to utilize the same bandwidth is called Frequency Division Multiple Access (FDMA).

FDMA divides the available bandwidth into multiple sub-bands each of which is able to carry a signal. Therefore, FDMA enables concurrent transmissions over a shared communication medium. Same frequency channel is used and the frequency band is divided among users for each to use a different channel to send huge amount of data. The signals must be kept apart to avoid interference [1]. FDMA was used in first generation analog systems which operate in range of kilohertz but in this paper the rate of signals in FDMA is improved in such a way that they can be operated in gigahertz at the cost of using more power. One of the main applications of FDMA is mobile communications which highly uses microstrip patch antennas.

Microstrip antennas are exclusively preferred for their light weight, reduced size and are affordable. Multiband antennas are used in applications with switching frequencies. With the use of inset feed technique, one can maintain the planarity of the microstrip patch antenna. It also provides more spurious feed radiation, easy fabrication and proper impedance matching [2]. The slots in the patch behave as resonant radiator and can enhance the gain for high permittivity substrate. The truncated edge provides circular polarization. The parameters that define the quality of an antenna are: Bandwidth, Gain, Directivity, Reflection coefficient, VSWR, Polarization, Radiation pattern [3].

Similar work can be observed in [4], where the antenna is stacked. Comparatively, the designed antenna proves to be efficient in simple structure, easy feed and fabrication, thus cost efficient. But one of the discrepancies is that the gain is relatively low. Proposed antenna is preferred for low cost and reduced design complexity. The main advantages are that, a single feed without shorting pin is sufficient to make the patch resonate at the multiple band frequencies Hence the proposed antenna is efficient in size and easy to fabricate as it is a single patch antenna.

Proposed System:

FDMA allows multiple users to send data through a single communication channel, such as a coaxial cable or microwave beam, by dividing the bandwidth of the channel into separate non-overlapping frequency sub-channels and allocating each sub-channel to a separate user.

The block diagram of FDMA with proposed scheme is shown in Figure 1. As mentioned the transmitter is mainly a cascade of a source encoder, a channel encoder and a modulator while the receiver is a cascade of a demodulator, a channel decoder and a source decoder. The purpose of this project is to simulate the basic components of an analog communication system using MATLAB programming. An AM modulator and a corresponding receiver are simulated.

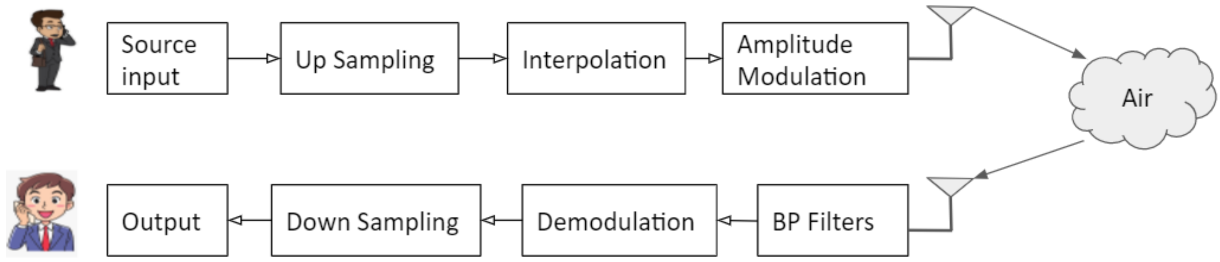


Figure 1 Block diagram of FDMA communication System

Generally, for telecommunication messages are voice signals but these are analog in nature by converting them in to ".wav" (continuous signals) format it's easy to analyze, modify and propagate them. This can be done in Matlab with the help of *audiorecorder* tool, takes voice as input and convert them into digital form [7].

A. Transmitter:

Transmitter block begins with taking source signals in continuous format (.wav) files. Assume two sample signals. After getting input check for each sample that these are monotonic signal if not convert them to monotonic. Then analyze the signals by convert them from time domain to frequency domain using Discrete Fourier Transform (DFT) or Fast Fourier Transform (FFT), converts continuous signals to discrete signals.

Now up-sample the source signals such that they met the nyquist condition ($f_{s\,amp}$>= $2f_{max}$). After encoding the source signals interpolate the signals by making them of same length using zero padding channel encoding [8]. Then generate two carrier signals of frequencies 2.43 GHz (F1) and 2.63 GHz (F2) or in frequency frame of 2.41-2.47 GHz and 2.58-2.70 GHz respectively, as their return losses are less than -10 dB and VSWR ranges in 1-2. In this paper frequencies used are 2.43 GHz and 2.63 GHz for two sample signals. Selecting two carrier frequencies for two sample signals which enable to carry a signal signifies FDMA.

By using Amplitude modulation, multiply sample signals with corresponding carrier signals, eases multiplexing. Perform FFT on these signals to analyze them. After modulation add all the signals. We get a single signal. Here comes the scenario of designed antenna. As the signal is in desired frequency; give it as input to the antenna. It resonates the signal through channel (Air in this case) however noise adds to the signal.

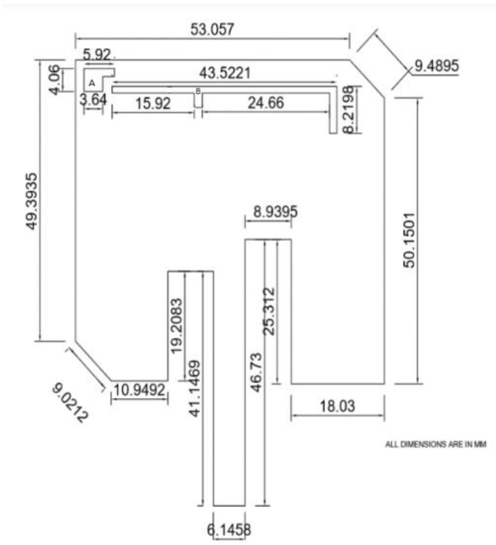
Modulated signal; $M_i = C_i * S_i$; $M_i = 2\cos\left(\frac{2\pi n F_i}{F_{si}}\right) * S_i$ (5)

Message signal, $MSG = \sum M_i$ (6)

B. Antenna Design:

The designing patch antenna should be light weight, and reduced in size so the length, width of the patch is determined with the material type and relative permittivity of the substrate [5]. The patch length, and width are derived from the equations from [3]. A patch with dimensions 53.05 mm x 56.50 mm is designed from equation (1), (4). The rectangular patch is truncated by 6.70 mm and 6.90 mm at the right and left edge respectively. FR_4 is preferred as the substrate material since it is affordable, accessible and easy to fabricate. It also has high mechanical and dielectric properties for heat and moisture resistance.

The dielectric substrate FR_4 with thickness 1.6mm and ε_r of 4.4 is used in design. The conducting layer is Copper with a thickness of 0.05mm and during the process of fabrication. In figure 2, the top section view of designed antenna with measurements (all dimensions are in mm) and slots made on patch is shown. Each slot and cut made on antenna is on purpose. The main slot represented by region B was slotted to excite the antenna in multiple bands. The L shaped region A is a combination of 2 slots, one helped in increasing reflection coefficient at 2.435 GHz and the other hand low current density distribution [3].



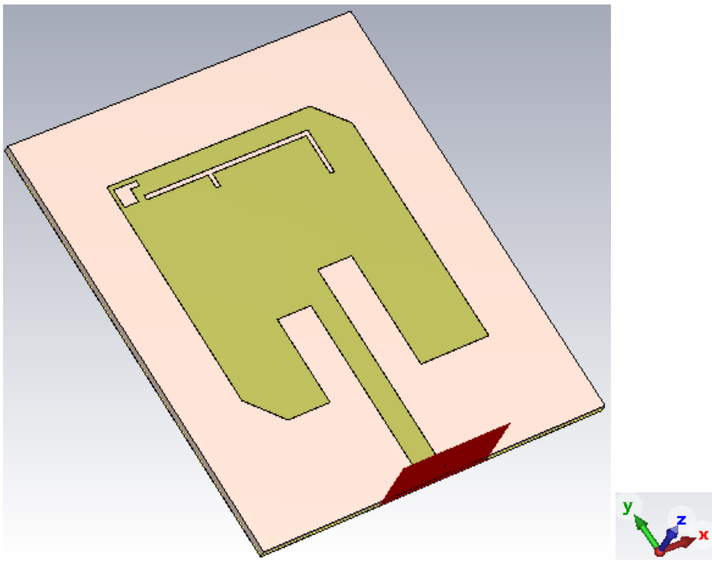
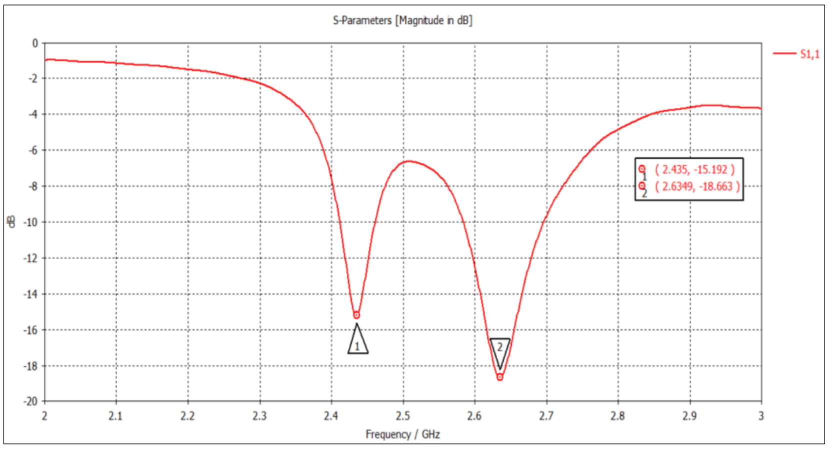


Figure 2a Geometry of Antenna
Figure 2b 3D view of designed Antenna

The truncated edge at the top right and bottom left of the patch provides right hand circular polarization. Similarly, left hand circular polarization can be obtained by truncating the top left and bottom right edges [6].

Inset feed technique is preferred as it is easy to use with array and obtain input match. Hence the antenna can also be developed into array for better directivity and less power loss. The designed antenna should be deployed in FDMA communication system to Trans-receive signals.

The Fig.3 indicates that the antenna resonates at 2.43 GHz and 2.63 GHz. A band pass filter can be attached to the antenna to filter the additional resonating bands at 2.63 GHz. The filter has to be designed to pass bands between the frequencies 2.4 - 2.7 GHz. This helps in restricting interference of signals resonate in other frequencies than the desired frequency bands. The Voltage Standing Wave Ratio (VSWR) values fall in the desired range for the desired band frequencies. Antenna is designed and simulated using CST R2021.



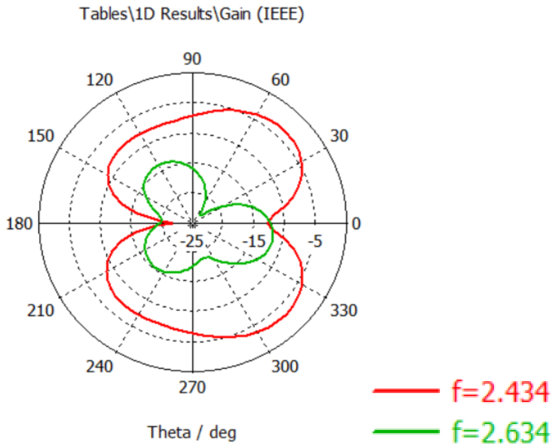


Figure 3a Return Losses of designed antenna (S11 in dB)
Figure 3b Gain of antenna at desired frequencies

Table 1 - Parameters

Marker (Fig 2)	Frequency (GHz)	S_{11} (dB)	VSWR	Gain (dBi)
1	2.435	-15.192	1.421	0.78
2	2.634	-18.663	1.264	1.29

C. Receiver:

At the side of receiver there is an antenna which intakes the signal, which is EM wave, and induces electric pulses, frequency and amplitude as parameter. There is possibility of designing two Band Pass filters one with bandwidth of 30 MHz (2.43 -2.46 GHZ) and another of 45 MHz (2.63 – 2.675 GHz). Also set the margin for filters. Set the frequency and amplitude parameters. Normalize frequency parameters with the rate of signals. Design band pass filter with the help of *fdesign* tool. Then apply filter and capture the received filter in the Band pass filter. Plot and analyze the signal with the help of FFT. Here comes the scenario of Band pass filters (BPFs).

Margin for filters, mar = 0.4*abs (F1-F2); where F1 and F2 are carrier frequencies. (7)

Then demodulate the signal with square law demodulation technique. In square law demodulation the received signal is multiplied with the carrier signal having same frequency. This separates the carrier signal from source signal and gives the source signal as output. As the source signal is audio or voice signal whose frequency ranges from (20Hz – 20 KHz) the signal (output of demodulation) must be passed through low pass filter to retrieve the original (source) signals. Design band pass filter with the help of *fdesign* tool after setting frequency and amplitude parameters. Each signal is passed through respective low pass filters and the source signal is separated from the channel. Reconstruct the signal is happened with down sampling. After reconstruction the signal reclaims its original state and these can be played using Matlab tool.

Simulated Results:

The simulated results of the antenna have seen in above section. Here simulated the results of designed FDMA communication system after deploying the antenna at desired frequencies using Matlab. Figure 4 shows the plot of spectrum of each signal using FFT.

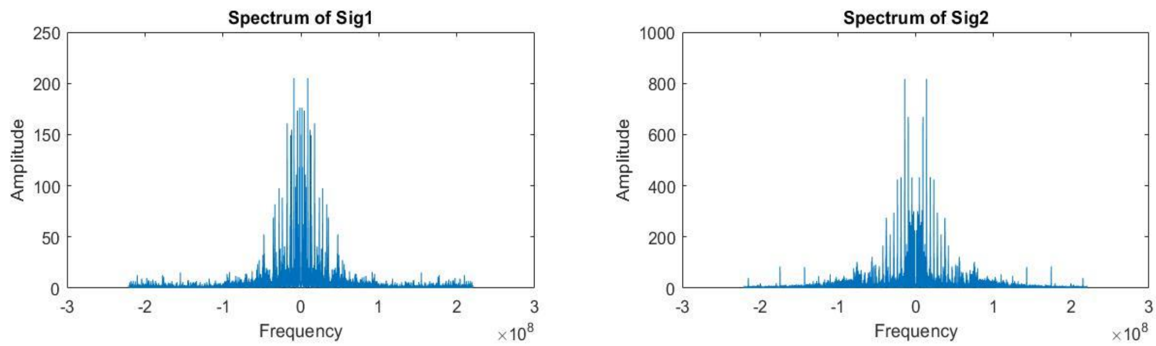


Figure 4 Spectra of Sample signals

Figure 5 shows the plot of modulated signal after multiplying it with carrier frequencies (F1 & F2). The lobes of signal 1 are centered at 2.43 GHz and signal 2 at 2.63 GHz.

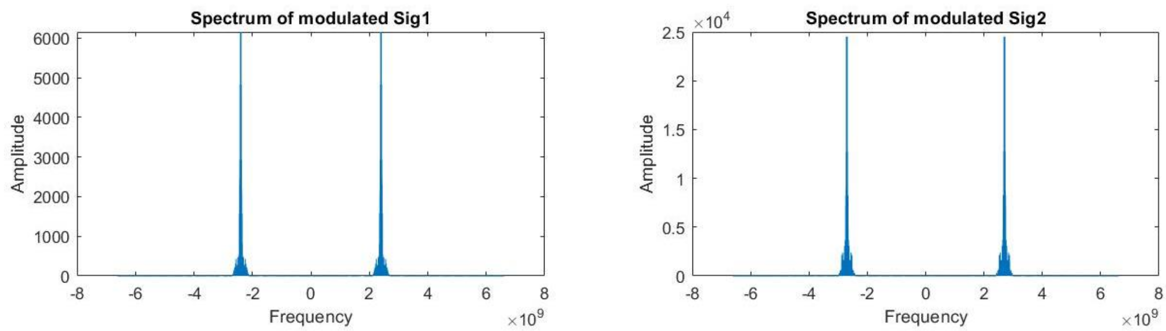


Figure 5 Spectra of Modulated signals

Figure 6 depicts the plot of received signal at receiver side also the signals 1 and 2 are centred 2.43 GHz and 2.63 GHz respectively, which is same as transmitter side. The red and green dotted lines represent the bands that should be allowed through Band pass filters. The bands cover the signal 1 and signal 2. Then these are passed to demodulator.

In figure 7, the spectra of demodulated signals can be seen, whose frequencies are centred at 4.86 GHz and 5.26 GHz, twice of maximum frequencies met the condition of nyquist. Then the signals are passed through low pass filter.

Now the signal and channel are separated and the channel frequency is set to 0 Hz. The separated signals from channel can be played using sound tool. This gives sound of the signal output which is same as source signal sound. The response of filters can be analyzed using *fvtool* in Matlab

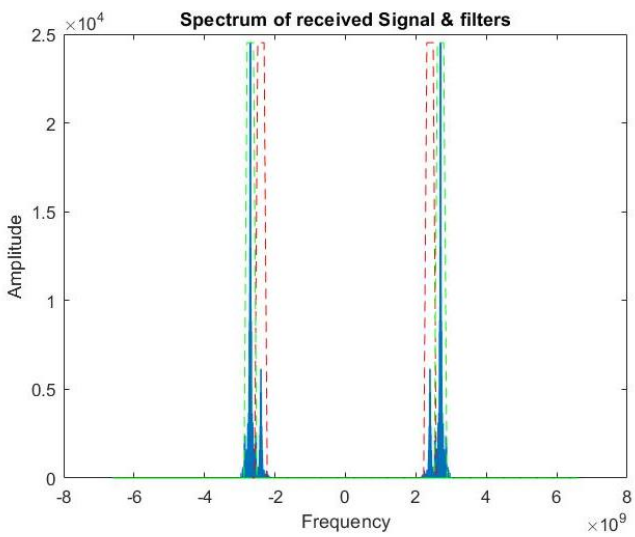


Figure 6 Spectra of signal at Receiver Antenna

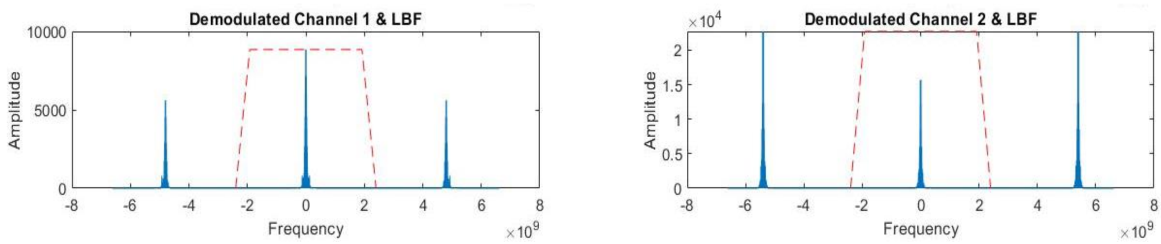


Figure 7 Spectra of Demodulated Signals

Conclusion:

Designed and exploited a tool to convert voice to continuous signals. A FDMA communication system deployed with a low profile microstrip patch antenna, frequency ranging from 2-3 GHz, designed, simulated and analyzed. The simulated results show the effective communication (transmitting & receiving) at 2.43 GHz and 2.63 GHz. This makes it eligible to work for telecommunication applications.

Future work:

Although FDMA is suitable for telecommunication OFDM is preferable due to it its ability to cope with severe channel conditions and provides resilience against narrow band fading that occurs as a result of reflections and the general propagation properties at these frequencies. So updating FDMA to OFDM makes it more compact and efficient.

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