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An Innovative High-Frequency Wireless Communication Technique Inspired by Multi-Frequency Carrier Signals

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An Innovative High-Frequency Wireless Communication Technique Inspired by Multi-Frequency Carrier Signals

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***Abstract* — Modern intelligent broadcasting technologies like IoT and wireless communication mediums are playing an important role to connect multiple heterogeneous devices. It fulfills the requirement to achieve the advanced developed communication system. This paper describes a data transmission technique using a high-frequency generator reflex klystron. Here high-frequency Multi-level frequency shift techniques with the help of a single reflex klystron namely M-ary High-Frequency Shift Keying (MHFSK) are proposed. Reflex klystron plays the main role to generate multiple independent high-frequency signals. In this scheme, the high-frequency carrier signal is selected through a sequence of binary bits which control the reflector voltage. As a result, this modulation system creates multiple high frequencies which act as an important parameter of this proposed multi-frequency modulation scheme. The main goal is to improve the error performance of the associated bit rate. As a result, the overall efficiency is increased compared to other binary digital modulation system. This new concept has been verified through an experimental framework.**

Keywords—Reflex Klystrons, Multi-level frequency generation, High-frequency shift keying

I. INTRODUCTION

The demand for wireless interconnection between smart, intelligent devices is increasing day by day. In modern wireless communication, M-ary modulation is the present trend. Which evolve M-ary ASK, M-ary PSK, M-ary FSK, M-ary QAM.[1] At, the high-frequency information can only be transferred through variation of frequency as mention in [2], where only one bit of information out of two possible signals can be transferred during every T_b seconds.

If we increase the level of variations that increase the data rate or spectral efficiency by the factor of several bits transmitted per symbol. Not only the bit rate or spectral efficiency the level of security plays an important role in this proposed modulation technique due to high frequency.

Therefore, this paper describes an innovative modulation method of namely "M-ary High-Frequency Shift Keying (MHFSK) "for Wireless Communication Technique Inspired with multiple-frequency Carrier signals" by using a single Reflex klystron.

A. M-ary Signaling

In binary signaling, the speed of transmission is approximately 1 bit/symbol. For conserving bandwidth and for a higher rate of transmission, a few of the binary digits may be grouped and converted to a multilevel symbol(baud). The multilevel used to generate multifrequency MHFSK, thereby reducing the channel BW by a factor n, if n bits are grouped to produce $M=2^n$ level baseband signal. [3,4]

B. Reflex Klystron

Reflex klystron is a single cavity oscillator used as a high-frequency signal generator [5]. From the characteristics of Reflex Klystron, it is established that Amplitude Modulation (AM) and Frequency Modulation (FM) are inherently inseparable. So, only pulse waveforms are used to generate the carrier's frequency.

C. Channel Model

The received signal profile is mainly dominated by the characteristics of the medium through which it is transmitted, popularly known as the channel model. The channel estimation is done based on the three-channel models namely additive white Rayleigh, Gaussian noise (AWGN), and Rician [6].

a) Additive White Gaussian Noise Model

When a noisy channel is considered to transmit the signals the AWGN model [7] is generally used. The mathematical expressions of the received signal are the sum of the transmitted signal and the associated background noise. It is the basic communication model.

b) Rayleigh fading model

The primary cause of Rayleigh fading [8] is the multipath signal transmission. It is a practical model for the propagation of the signal through ionospheres and the troposphere and well-established model used suburban environments for radio signals transmissions. When transmitter and receiver are not in the line of sight then this type of fading is dominant.

C) Rician Fading Model

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The Rician fading (RF) model [9] is analogous to the Rayleigh fading model. Though here some strong dominant attribute exists. These attributes are non-fading i.e., stationary signals and this is generally categorized as the line of sight (LOS) communication.

This paper focuses on high-frequency modulation and demodulation systems. Our proposed High-Frequency Wireless Communication Technique namely MHFSK in AWGN can be improved by increasing modulation order. This High-Frequency Modulation Technique with Rayleigh and Rician channel performance can further be improved by increasing diversity order. And also, this proposed Communication system with the Rician channel can furthermore be improved by increasing N-factor.[10] A High-Frequency Wireless Communication system generally has better performances compared to other techniques in terms of BER and gain in E_b/E_o. The above M-ary modulation gives a better result at the Rician channel compared to another modulation method [11]. From the practical point of view majority of a high-frequency wireless communication system use LOS.

The organization of this paper is as follows:

After an introduction at the beginning, the literature survey has been considered. Then the theoretical concepts of the High-Frequency Wireless Communication Technique namely MHFSK using a Reflex klystron have been incorporated. Finally, the experimental setup is described in the next section, followed by experimental results. The paper concludes some highlighting points regarding secure, low BER, and high-speed communication and future scopes to extend the model.

II. LITERATURE REVIEW

High-Frequency Wireless Communication Technique has an advantage in terms of power efficiency if it is used for low power and low data rate transmission equipment. The power efficiency of this modulation increase as the signal alphabet increases. But at frequency variation is restricted to the frequency of the signal, not the amplitude or phase. Design and implementation of high-frequency FSK modulation and demodulation technique are proposed and also verified that binary data transmission is possible with the help high-frequency data transmission scheme [2]. This technique sends only one bit of information out of two possible signals carry by each symbol in every T_b second.

III. M-ARRAY HIGH-FREQUENCY SHIFT KEYING (MHSFK) GENERATION USING A REFLEX KLYSTRON

Multiple numbers of predefined high-frequency signals are used in this shift keying technique so that two or more bits of encoded information carried by each signal element resulting in M-array data transmission. So, the bit rate is always greater than the symbol rate (bauds). During a specific signal interval, the M-array data transmission sends only one of M possible signals.

A. *Theoretical Evaluation of the performance M-array FSK schemes.*

The probability of error in terms of bit and symbol error rate of M-array FSK is obtained by the MATLAB program [12] as shown in figurer 1 and 2.

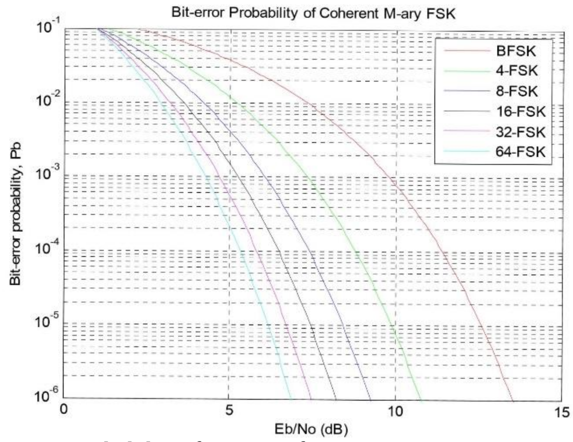


Figure 1. *Probability of Bit-error for M-array FSK*

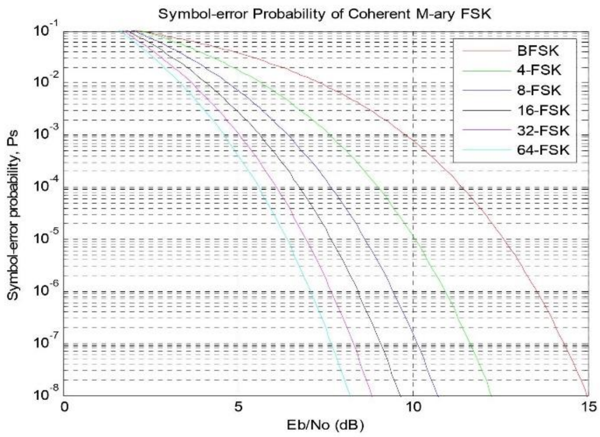


Figure 2. *Probability of symbol-error for M-array FSK*

The above two figures show the error performance improvement as the level of FSK (M-array FSK) is increased. In digital communication, error performance is considered in terms of E_b/N_o. Our modulation technique is similar to M-array FSK technique.

B. *M-array High-Frequency shift keying*

In the Multi-tone signaling modulation, the binary data sequence is segmented into $n = \log_2 M$ bits each. The n order pair of M messages is denoted explicitly. There are M no of possible signals with pre-defined different frequencies to express those M possible messages. $M=2^n$ and time-period $T= nT_b$ where n is an integer. Each of the M-signals is called a symbol. These signals are generated by changing the amplitude, phase, frequency, or combined forms of a carrier in M-discrete steps.[13] The symbols' rate or baud is defined by bit rate and represented by $1/T_b$ i.e., bit per second (bps) and bauds are the same.

The Mathematical representation [14] of M-array High-frequency modulation is given below,

$$S_m(t) = \sqrt{\frac{2E_s}{T}}\cos\{2\pi(f_c + (m-1)\Delta f)t\}$$

For m= 1, 2…….M and $0 \le t < T$

Where $\Delta f = f_m - f_{m-1}$ $with\, f_m = f_c + m\Delta f$

C. System Model

The analog information signal is passed through Pulse Code Modulation and the bitstream is segmenting to 3 bits/segment. The 3-bit output is fed to a 3-to-8-line decoder. The decoder outputs are used to control eight different solid-state switches to pass pre-defined voltage (generated from the regulated voltage at 8- different voltage levels) outputs according to the segment bit pattern.

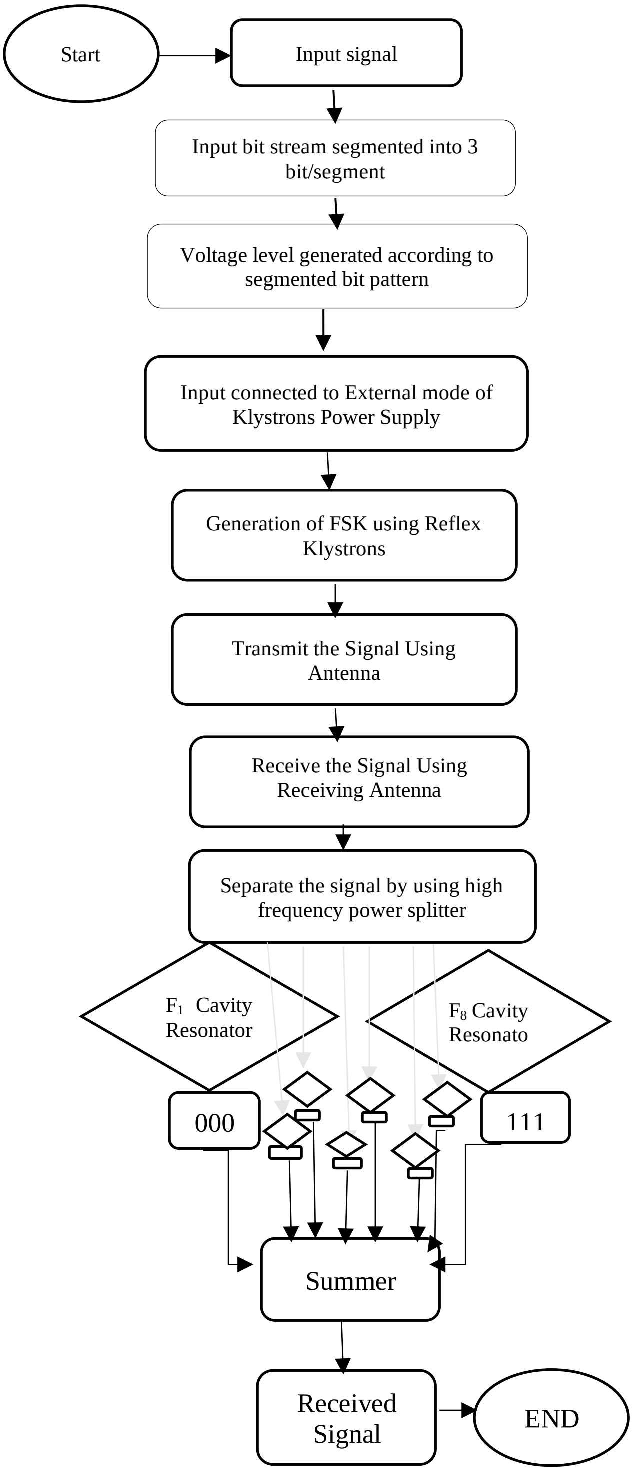
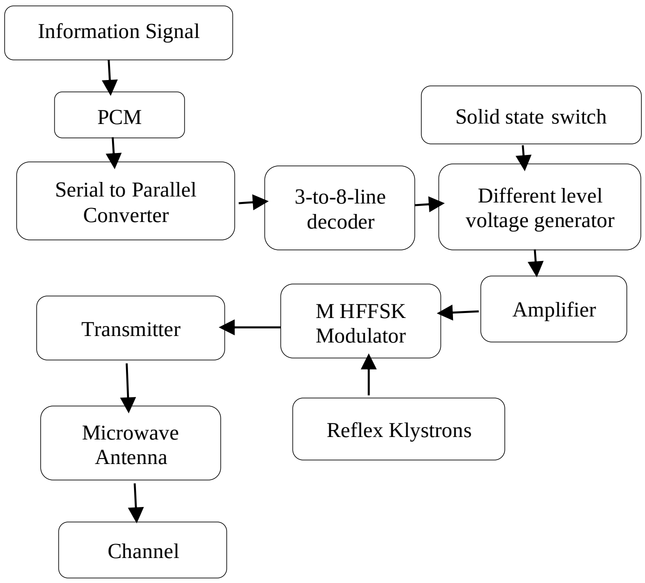


Figure 3. *Flow chart for M-ary FSK Modulator*

These voltage levels, through amplifier/buffer, are used to drive a reflex klystron power supply in external mode. As a result, the reflex klystron would generate 8 pre-defined frequencies according to repeller voltage levels. Different high frequencies carry the information of the message signal. Reflex klystron output is connected to the channel through a suitable transmitter. Any type of microwave antenna used for signal transmission. At the receiving end, the signal is received by a receiving antenna and applied to 8 different cavity resonators. According to the received signal frequency, a particular cavity resonator would become high. The outputs of all cavity resonators are connected to an 8-to-3-line encoder and then a parallel to serial converter. The converter output gives us the received bitstream. Due to experimental limitations, we defined 8-ary high-frequency shift keying instead of M-ary frequency.



1. Information Signal,
2. PCM
3. Serial to Parallel Converter
4. 3-to-8-line decoder

5a) Different level voltage generator

5b) Solid state switch

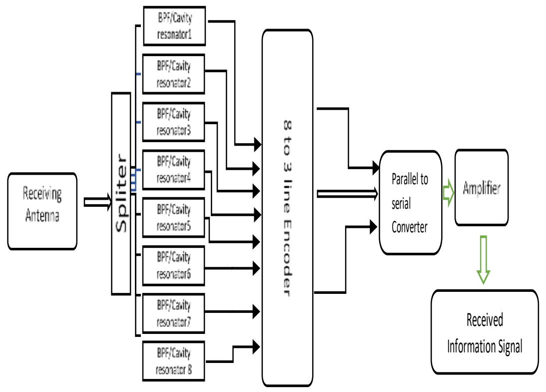
6. Amplifier

7a) M-ary FSK Modulator

7b) Reflex Klystrons

8. Transmitter
9. Microwave Antenna
10. Channel

Figurer 4. *Block diagram of proposed high-frequency M-array FSK Transmitter*



1. Receiving Antenna
2. High-frequency Splitter
3. 8 no. Cavity resonators (1 to 8) with 8 different Resonating frequencies
4. 8-to-3-line Encoder
5. Parallel to serial Converter
6. Amplifier
7. Received Information Signal

Figure 5. *Block diagram of proposed M-ary High-Frequency Shift Keying (MHFSK) receiver section.*

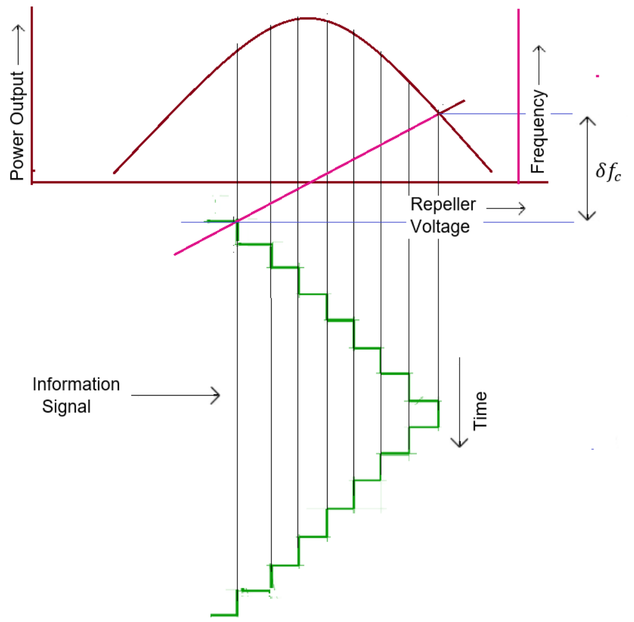


Figure: 6. *Klystron Characteristics: Repeller Voltage vs. Power & Frequency relationship for proposed M-ary High-Frequency Shift Keying (MHFSK)*

IV. RESULT ANALYSIS

Beam voltage = 225volts. The mode of oscillation must have the largest peak power is selected for operation. The repeller voltage is adjusted at -75 volts to obtain maximum peak power of 13.54 mW. The corresponding frequency of oscillation as obtained in the wave-meter is 9.95 GHz. The power of the half-power point is 6.77mW and it is obtaining by adjusting the repeller voltage. Next tuned to repeller voltage of klystron power supply at - 71volts (lower value) and -81volts (upper) respectively.

Table1. Generated carrier frequencies corresponding to 3-bit message segments.

Steps	M-bit/Symbols	CFS
0	000	F_0
1	001	F_1
2	010	F2
3	011	F_3
4	100	F_4
5	101	F_5
6	110	F_6
7	111	F_7

At the lower half-power point the frequency of operation as observed in the frequency-meter is 9.85GHz. The amplitude of the message data will be suitably adjusted and properly placed to have its lower peak value claimed at -71 volts level and its upper peak at -81volts level as illustrated in fig 6. After that, this voltage gape is divided into 8 levels to generated 8 different frequencies to generate 8-ary HFSK signals.

Table2.Repeller voltage vs. Generated frequencies (in GHz)

Steps	Voltage level(volts)	Frequency (GHz)	CFS
1	-71	9.95	F_1
2	-72	9.94	F_2
3	-73	9.93	F_3
4	-74	9.9267	F_4
Ref	-75	9.92	F_{ref}
5	-76	9.9	F_5
6	-78	9.89	F_6
7	-80	9.87	F_7
8	-81	9.85	F_8

Therefore, adjust the value of beam voltage denoted as V_0 = 250volts. Repeller voltage for peak power V_{ref} = -75volts. Half power repeller voltages V_1= -71 volts, V_8= -81 volts, and corresponding frequencies are F_c=9.92GHz.

F_1 = 9.85GHz, F_8 = 9.95GHz. Frequency deviation (δfc) =9.95- 9.85=100MHz.

This 100 MHz frequency range is divided into 8 different frequency levels at 8-arrayHFSK modulation.

Table3. Frequency deviations for different bit symbols

No of Tone	Tone (MHz)	Symbol
0	175	000
1	125	001
2	75	010
3	25	011
4	-25	100
5	-75	101
6	-125	110
7	-175	111

Cavity data at the receiver circuit:

(All other passive RF components used are standard X- band components.)

Table4. Centre frequencies outputs for different cavity states

Cavity states	Center frequency	BW
1	9.95	<12.5MHz
2	9.94	<12.5MHz
3	9.93	<12.5MHz
4	9.9267	<12.5MHz
5	9.9	<12.5MHz
6	9.89	<12.5MHz
7	9.87	<12.5MHz
8	9.85	<12.5MHz

On experimentation, it has been found that the output bitstream obtained at the receiving end is the replica of the transmitted bitstream having all the superior features of the M-array HFSK system.

V. CONCLUSION

The main objective of this paper is to transmit information signals at high frequency by the 8-ary HFSK technique for long-distance communication. The 8-ary FSK modulation technique has been used to modulate the signal to support long-distance communication using a microwave tube. This experimental process is applicable for a higher order of HFSK modulation techniques also. This paper highlights the scope of high-speed data transmission. The error control framework is also under consideration along with the existing state-of-the-art module.

References

[1] Sklar B. Digital communications, vol. 2. Upper Saddle River, NJ: Prentice-Hall, 2001.

[2] Pal Prashnatita, Sahana Bikash Chandra, Mallick Amiya Kumar, and Poray Jayanta, "Generation of Encrypted FSK RF Signals for Secured Communication Inspired with HighFrequency Technique," International Conference on Recent Trends in Artificial Intelligence, IoT, Smart Cities & Applications (ICAISC-2020), Available at SSRN: https://ssrn.com/abstract=3610690

[3] Richard W. Middlestead, "Frequency Shift Keying (FSK) Modulation, Demodulation, and Performance," in Digital Communications with Emphasis on Data Modems: Theory, Analysis, Design, Simulation, Testing, and Applications, Wiley, 2017, pp.207-225I.

[4] S. Jacobs and C. P. Bean, "Fine particles, thin films, and exchange anisotropy," in Magnetism, vol. III, G. T. Rado, and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350

[5] Fumiyaki Adachi, "error Rate Analysis of Differentially Encoded and detected 16-APSK under Rician fading," IEEE Transactions on Vehicular Technology, Vol. 45, No. 1, February 1996.

[6] S. A. Hassan and M. A. Ingram, "SNR Estimation for M-ARY Non-Coherent Frequency Shift Keying Systems," in IEEE Transactions on Communications, vol. 59, no. 10, pp. 2786-2795, October 2011, DOI: 10.1109/TCOMM.2011.080111.090627.

[7] Jiho Ryu, Jeong Keun Lee, Sung-Ju Lee and Taekyoung Kwon, "Revamping the IEEE 802.11a PHY Simulation Models," MSWim 08, October 27-31, 2008, Vancouver, BC, Canada.

[8] A. Alimohammad, S.F.Fard, B.F.Cockburn and C.Schlegal, "Compact Rayleigh and Rician fading simulation based on random walk processes," IET Communications, 2009, Vol. 3, Issue 8, pp 1333-1342.

[9] Fatima Faydhe AL-Azzawi, Saleim Hachem Farhan, Maher Ibraheem Gamaj "M-FSK in Multi Coding and Channel Environments," International Journal of Soft Computing and Engineering ISSN: 2231-2307, Volume-5 Issue-3, July 2015

[10] M. K. Simon and M.-S. Alouini, Digital communication over fading channels. John Wiley & Sons, 2005.

[11] Xuegui Song, Julian Cheng, and Mohamed-Slim Alouini, "High SNR BER Comparison of Coherent and Differentially Coherent Modulation Schemes in Lognormal Fading Channels," IEEE Communications Letters, vol. 18, no. 9, pp. 1507-1510, September 2014.

[12] Samual Y Liao, "Microwave Devices and Circuits,"4th edition, Pearson Education Pvt. Ltd, New Delhi,2003, pp.380.

[13] M. S. Islim and H. Haas. Modulation techniques for Li-Fi, ZTE communications, 14(2):29–40, 2016.

[14] C. E. Shannon. "A mathematical theory of communication,"Bell Sys. J., 27(3):379–423, 1948.