Construction of Frequency-Hopping System Using Carrier-Signal Generator

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***Abstract*—To clearly understand wireless communication technology for educational purposes, an inexpensive wireless modulation and demodulation system is required. A simple carrier-signal generator can generate a carrier signal, and a spectrum analyzer can search for a peak frequency and be controlled by a PC. Therefore, a frequency-hopping wireless transmitter and receiver system can be constructed using a carrier-signal generator and spectrum analyzer. We constructed a frequency-hopping transmission system using a carrier-signal generator and spectrum analyzer. To validate this system, we evaluated the peak frequency detection probability and compared it with theoretical values. The results indicate that when the hopping time interval was 2000 ms, the peak frequency detection probability almost coincided with the theoretical values.**

***Keywords*—Signal generator, Spectrum analyzer, Frequency-hopping, Peak frequency detection probability, Sweep time.**

I. INTRODUCTION

A radio frequency (RF) communications trainer can generate RF modulated signals or carrier signals, thus helping wireless communication engineers and students understand wireless communication technology. However, a demodulation system is also required to clearly understand wireless communication technology for educational purposes. A general purpose vector signal analyzer [1]-[3] can demodulate modulated signals. However, such vector signal analyzers are very expensive. On the other hand, a spectrum analyzer can search for peak frequencies and be controlled by a PC. We previously constructed a frequency-hopping [4] wireless modulation and demodulation system [5] by using an RF communications trainer [6] and spectrum analyzer [7].

Not only an RF communications trainer but also a simple carrier-signal generator (e.g., USG-LF44) [8] can generate a carrier frequency. The output carrier-signal frequency of such a carrier-signal generator can be controlled using a PC. Therefore, a frequency-hopping wireless modulation and demodulation system can be constructed with such a signal generator and spectrum analyzer.

For this study, we constructed a frequency-hopping transmission system in the RF band using the simple carrier-signal generator USG-LF44 [8], and spectrum analyzer GSP-730 [7]. To validate the system, we evaluated the peak frequency detection probability p and compared it with theoretical values. The peak detection performance depends on the sweep time T_{ST} of a spectrum analyzer. We also evaluated the effect of T_{ST} of GSP-730 on p.

II. CONSTRUCTED FREQUENCY-HOPPING SYSTEM

Figure 1 shows the configuration of our frequency-hopping modulation and demodulation system. The simple carrier frequency signal generator, USG-LF44 and the spectrum analyzer, GSP-730 were connected to controller PCs with USB cables. Frequency hopping is carried out from 870 to 918 MHz with a constant frequency interval Δf. The controller PC connected to USG-LF44 can control Δf and the hopping time interval T.

Table 1 shows the specifications of GSP-730. A command to search for the peak frequency and send it back is transmitted from the receiving controller PC to GSP-730. The notation τ is the command transmission period from the PC to search for the peak frequency.

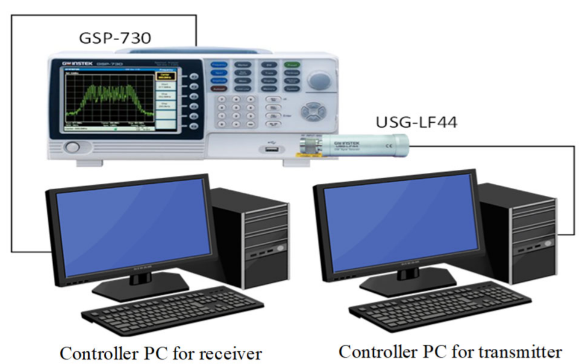

Figure 1. Frequency-hopping modulation and demodulation system

Table 1. Specifications of GSP-730

Center frequency	894 MHz
Span	50 MHz
Sweep Time	300, 400, 500, 4500 ms
Resolution Bandwidth	300 kHz

III. PEAK-FREQUENCY DETECTION PROBABILITY

If the T_{ST} of the spectrum analyzer is larger than τ to search for the peak frequency, a peak frequency may not be detected. Therefore, τ_{max} expressed with the following equation, is the required duration to detect a peak frequency.

$$\tau_{\max} = \max(\tau, T_{ST}) \quad (1)$$

If τ_{max} is smaller than or equal to T, the peak frequency detection probability p becomes 1 since all hopping peak frequencies can be detected. On the other hand, if τ_{max} is larger than T, not all peak frequencies can be detected.

Figure 2 shows the relationship between the number of hops N_T and number of detected peak frequencies N_P when τ_{max} is larger than T. Assuming that the peak frequency is detected N_P times within the time of $T \cdot N_T$, the following equation holds,

$$T \cdot N_T = \tau_{\max} \cdot N_P. \quad (2).$$

Then p can be expressed as

$$p = \frac{N_P}{N_T} = \frac{T}{\tau_{\max}} \quad (3).$$

Finally, the relationship among p, T, and τ_{max} is expressed as the following equation,

$$p = \begin{cases} 1 & (T \geq \tau_{\max}) \\ \dfrac{T}{\tau_{\max}} & (T < \tau_{\max}) \end{cases} \quad (4)$$

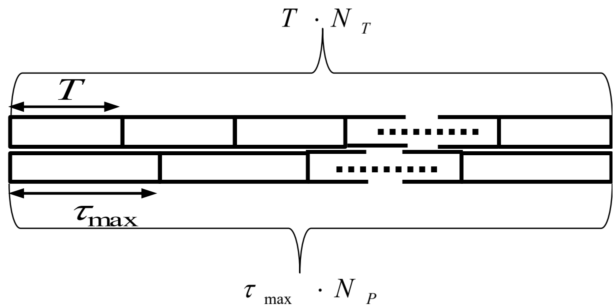

Figure 2 Relationship between the N_T and N_P of the detected peak frequencies

IV. PERFORMANCE EVALUATION

We evaluated the peak frequency detection probability p assuming the allowable frequency detection error of ±0.2 MHz and Δf=1MHz. Figures 3-6 show the relationship between p and the peak frequency search command transmission period τ as parameters of the sweep time T_{ST} when the hopping time interval T=2000, 700, 600, and 500 ms, respectively. For comparison, theoretical values were also plotted as solid lines.

From these figures, the p of T_{ST}=4500 ms almost coincided with the theoretical values even when T was smaller than or equal to 700 ms. When $T_{ST} \leq 500$ ms, however, the experimental value almost agreed with the theoretical value when T = 2000 ms, but when T = 700 or 600 ms, the experimental value degraded from the theoretical value when τ was smaller than T. The p of the experimental results significantly deteriorates from the theoretical ones when T_{ST} = T = 500 ms. This is seemingly because it became difficult to detect the peak frequency when T approached T_{ST} of the spectrum analyzer.

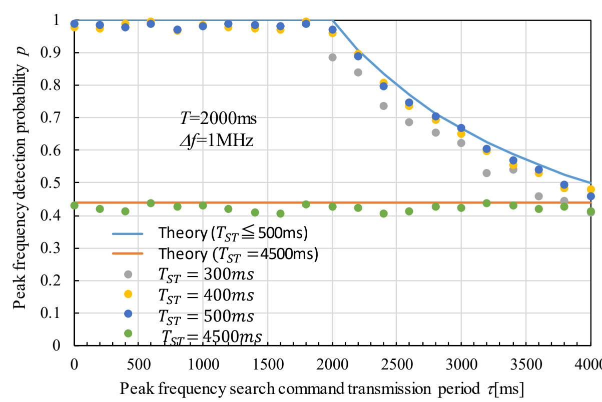

Figure 3. Relationship between peak frequency detection probability p and peak frequency search commnad transmission period τ as parameters of sweep time T_{ST} when hopping time interval T=2000 ms

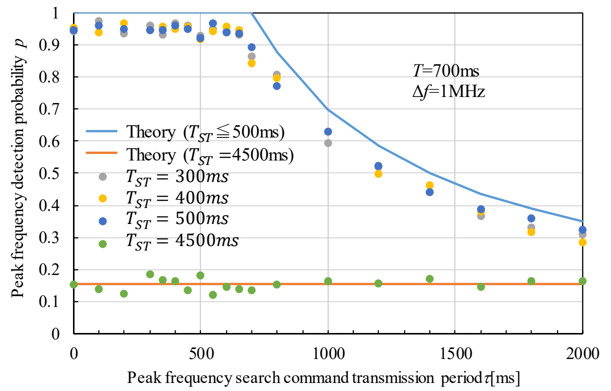

Figure 4. Relationship between p and τ as parameters of T_{ST} when T=700 ms

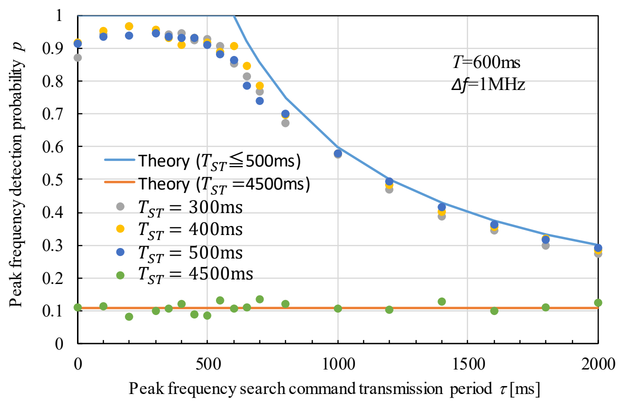

Figure 5. Relationship between p and τ as parameters of T_{ST} when T=600 ms

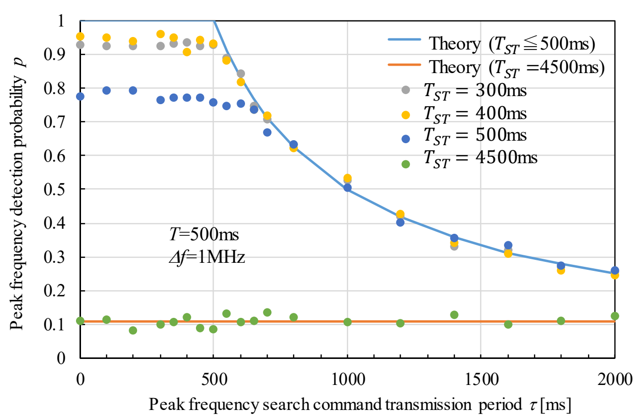

Figure 6. Relationship between p and τ as parameters of T_{ST} when T=500 ms

V. CONCLUSION

We constructed a frequency-hopping transmission system using a carrier-signal generator, USG-LF44, and spectrum analyzer, GSP-700. The results indicate that, when the hopping time interval was 2000 ms, the peak frequency detection probability almost coincided with the theoretical values. However, when the peak frequency search command transmission period approached the sweep time of the spectrum analyzer, it became difficult to detect the peak frequency, so the peak frequency detection probability decreased.

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