Instantaneous Frequency Measurement of Microwave Signals Using Frequency-Amplitude Transformation in Fiber Bragg Grating and Method of Additional Frequency Spacing

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Microwave photonic methods and systems for instantaneous frequency measurement of microwave signals based on "frequency-amplitude" conversion in most cases use fiber Bragg gratings (FBG) as the detection device due to the simple conversion of the past or reflected amplitude of the measured signal to its unknown frequency. Using standard fiber Bragg grating and modulation scheme with the difference frequency equal to the doubled frequency after modulation process, the measured frequency range will be 4-12 GHz. By applying π-phase shifted FBG with a triangular reflection profile and using advanced method of amplitude-phase modulation conversion by the Il'in-Morozov's method, the measured frequency range will be 0.4-24 GHz. The absolute error of systems, as a rule, equals to ± 200 MHz. The main metrological disadvantages of the instantaneous frequency measurement systems with Gaussian FBG is the monotonicity of the "frequency-amplitude" conversion characteristic in the area of its central wavelength, which reduces the accuracy of the conversion at "low" frequencies (0.4-4 GHz).

From the point of view on photonic methods and systems for instantaneous frequency measurement of microwave signals with FBG, we take the next principles: amplitude-phase modulation conversion of single optical carrier into symmetrical dual-frequency signal for additional frequency spacing (AFS); its modulation by unknown microwave frequency; and subsequent "frequency-amplitude" measurement conversion in FBG with Gaussian (not π-phase shift) reflection spectrum. Therefore, if the range of instantaneous frequency measurement system will be equal for 20 GHz, we have to write FBG with full width on the floor equal to 40 GHz. The AFS frequency have to be equal to 20 GHz. So, the low frequencies will be transferred and measured on linear slope of FBG. The initial AFS two-frequency radiation will be modulated by "low" microwave frequency components (0.4-4 GHz) and form four components of measured frequency: A_{11} and A_{12} for the first AFS component and A_{21} and A_{22} for the second. The measuring mechanism for given range will be the measurement of the modulation index m<1 of the beating envelope between A_{11} and A_{12} or A_{21} and A_{22}. The measuring mechanism for higher frequencies is described by the measurement of the modulation index m=1 of the beating envelope between A_{11} and A_{21}. This allows us additionally to determine the measured frequency range.

In paper, we described the principles of microwave photonic instantaneous frequency measurement system based on "frequency-amplitude" transformation in FBG. We identified possible way to improve their metrological characteristics in terms of available frequency range and resolution of "low" frequency identification by means of additional frequency spacing. Therefore, the low frequencies are measured on linear slope of FBG with good resolution and accuracy. The simulations show that the absolute error in this region is ± 40 MHz and in the "high"-frequency region ± 120 MHz.

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